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Orginal Article

Reconnecting with nature: reflections of the concepts of biophilia and biomimicry in interior design

Dürdane Aksoy Dolu[1], Emine Banu Burkut[2,*]

[1] Program of Construction Technology; Vocational School;
Antalya Bilim University; Antalya, Turkiye;
durdane.aksoy@antalya.edu.tr; ORCID: 0000-0003-0305-5683
[2] Department of Interior Architecture; Faculty of Art, Design and Architecture;
Fatih Sultan Mehmet Vakıf University; Istanbul, Turkiye;
ebburkut@fsm.edu.tr; ORCID: 0000-0003-0252-4054
[*] corresponding author

Abstract: This study critically examines the integration of biophilic design and biomimicry as complementary, nature-inspired strategies to promote sustainability and human well-being in interior architecture. While biophilic design aims to re-establish the emotional and psychological connection between humans and nature through direct and indirect natural elements, biomimicry focuses on imitating the functional intelligence of nature to develop energy-efficient, adaptable, and ecologically responsible solutions. Despite frequent conceptual overlaps in the literature, this research isolates their unique principles and explores their synergistic potential in the context of interiors. Using bibliometric analysis tools such as Web of Science, Scopus, VOSviewer, and R Studio Bibliometrix-Biblioshiny, the study maps publication trends, thematic networks, and underexplored research areas. While the findings reveal a growing academic interest in these concepts, they also highlight a significant gap between theoretical discourse and real-world application. The study advocates evidence-based integration of biophilic and biomimetic principles, supported by interdisciplinary collaboration and empirical case studies. Ultimately, the research offers actionable insights for academics and design professionals aiming to create indoor environments that balance user-centred well-being with environmental responsibility.

Keywords: biophilia, biomimicry, nature-based design, sustainability, interior design, nature-inspired interiors

1. Introduction

Humans are distinguished from other living beings by their capacity to transform and reshape nature. This characteristic creates both advantages and profound responsibilities in the human-nature relationship, while also complicating it [1]. Since the Industrial Revolution,

humans, who once lived in harmony with nature, have increasingly weakened this bond as they began to dominate it, accelerating the destruction of the natural environment. This change, which began in the 18th century and intensified throughout the 19th century, fostered humanity's ambition to establish superiority over nature and popularised the belief that nature should serve human needs. Such thinking has led to problems including the overuse of natural resources, pollution, and habitat loss, thereby disrupting the human-nature relationship. As a result, the bond between humans and nature has weakened, and environmental degradation has accelerated [2]. The growing environmental problems and their negative effects on human health have brought nature-based design approaches to the forefront. These approaches aim to ensure the efficient and long-term use of natural resources, minimise environmental impacts, and strengthen human–nature interaction. Ecological design, biomimicry, organic architecture, regenerative design, and biophilic design have all been developed and implemented with this aim. Biomimicry seeks to provide sustainable and environmentally friendly solutions by modelling the innovative strategies developed by nature over millions of years of evolution, while biophilic design seeks to strengthen the emotional bond between humans and nature and enhance the positive effects of nature within the built environment [3,4].

Biophilic design and biomimicry are two complementary approaches that reshape the human–nature relationship. Biophilic design reinforces the individual's connection to nature, while biomimicry offers innovative solutions to environmental challenges by modelling the sustainable cycles of natural systems. Combined, they provide holistic solutions in terms of aesthetics, functionality, and sustainability in interior design [5]. For example, a workspace enhanced with green walls enables direct interaction with nature while also saving energy through the application of biomimicry principles. In today's world, where the need for nature and the importance of environmental sustainability are increasingly recognised, biophilic design and biomimicry stand out as innovative approaches that enhance quality of life while supporting environmental awareness. These approaches contribute to both the psychological and physical well-being of individuals and to the conservation of natural resources. In this context, biophilia and biomimicry emerge as two fundamental design strategies that reinforce the human connection to nature while producing environmentally responsible solutions [4,6].

This study aims to demonstrate how the concepts of biophilia and biomimicry can be integrated into interior design to provide holistic solutions in terms of aesthetics, functionality, and sustainability. The study explores the connections between biophilia and biomimicry in the literature using bibliometric analysis, with scientific maps created and analysed using VOSviewer (Visualising Scientific Landscapes). The results highlight the contributions of the two concepts to sustainable interior design in both psychological and environmental dimensions. This study investigates how the combined application of biophilia and biomimicry offers effective solutions in sustainable interior design and examines the potential of these two nature-inspired approaches to reconstruct the human-nature relationship. Additionally, it evaluates the opportunities these concepts present for rebuilding this relationship and generating innovative solutions to environmental problems. To sum up,

Research Question: How can the integration of biophilic and biomimetic design approaches holistically enhance sustainability, functionality, and human well-being in interior spaces?

Hypothesis: The combined application of biophilic and biomimetic design strategies in interior spaces enhances both psychological well-being and energy efficiency more effectively than their isolated use.

Human beings possess a distinct ability to alter and reshape natural environments, a capacity that has enabled extraordinary technological and architectural advancements while

also contributing to profound ecological degradation. The rapid developments following the Industrial Revolution have greatly intensified this transformation, leading to increasing alienation from the natural world and playing a central role in the emergence of contemporary environmental crises. In response to these challenges, nature-based design philosophies have gained momentum, offering strategies to re-establish the disrupted relationship between humans and nature while promoting sustainable and responsible resource use.

Within this context, biophilic design emerges as a human-centred approach that emphasises the reintegration of natural elements – such as daylight, vegetation, water features, organic forms, and multisensory experiences – into the built environment to enhance psychological and physiological well-being. Conversely, biomimicry represents a problem-solving methodology grounded in the emulation of nature's time-tested forms, processes, and ecosystems to generate innovative, energy-efficient, and adaptive design solutions. Although both paradigms share the overarching aim of fostering ecological harmony, they differ in their operational focus: biophilic design centres on experiential and affective dimensions, while biomimicry is oriented towards functional and performance-based outcomes.

The integration of biophilic and biomimetic principles therefore offers a comprehensive and interdisciplinary design framework – one that not only promotes environmental sustainability but also prioritises human health, well-being, and resilience. Such a synthesis has the potential to redefine contemporary design practices by aligning technological innovation with ecological integrity.

Although previous studies have separately explored biophilia and biomimicry, the combined potential of these concepts, particularly in interior design, remains underexplored and fragmented across disciplines. This study aims to address this gap by providing a comprehensive analysis of their integration.

Nature is a broad concept encompassing all living and non-living beings, constantly renewing and evolving [7]. Industrialisation is a process that brings profound changes to the social and economic structures of countries and introduces undeniable challenges. Rapidly increasing urbanisation, coupled with inadequate infrastructure, housing, and transport networks, has placed societies in a difficult position; at the same time, it has triggered environmental issues such as air and water pollution, reducing the quality of life in modern cities.

Kaveh et al. (2024) emphasise that green infrastructure practices provide important outcomes not only in terms of aesthetics but also for climate adaptation and environmental sustainability [8]. In this respect, the study underlines the significance of nature-based solutions [9].

In particular, unplanned urbanisation has resulted in the concreting over of forests and agricultural land, causing the ecological balance to deteriorate [9]. Moreover, the impact of human activities on the environment has reached a level that gives rise to global issues such as climate change, biodiversity loss, and ecological degradation [1,10]. As this dynamic relationship between humanity and nature has shifted from harmony to a struggle for dominance, the ultimate loser has been humanity itself. With negative experiences increasing daily, people have been compelled to take measures against the destruction of nature. In this process, concepts such as sustainability, nature-friendly design approaches, and human-centred urbanisation policies have become part of daily life. Efforts to counteract the destruction of nature, global warming, and other environmental issues are now evident not only within the architectural community but across almost every profession that influences society. For example, subjects such as global warming, climate change, and environmental awareness have been addressed in many national and international photography and painting competitions. Industrialisation has caused not only physical destruction of nature and

humanity but also psychological harm to people, who are rapidly becoming distanced from nature and confined within artificial environments.

Nature-based design approaches have emerged from the need to re-establish a stronger connection between people and the natural environment and ecosystems, and began to develop in the 19th century. These approaches aim to protect natural environments, reduce environmental impacts, and use resources efficiently. Designing in accordance with the workings of nature, using natural materials, and taking account of environmental conditions are fundamental principles. In addition, the harmony and order found in nature continue to serve as a valuable guide for cities and architects [11].

Furthermore, nature-based design approaches aim to ensure the efficient and long-term use of natural resources, minimise environmental impacts, and strengthen human–nature interactions. Such approaches include Organic Architecture, Ecological Architecture, Regenerative Architecture, Biomimicry, and Biophilic Design. Organic Architecture is an architectural approach that seeks to design buildings in harmony with their natural surroundings and to establish a holistic relationship between humans, nature, and the built structure. This term generally refers to designs inspired by the forms, processes, and materials of nature. Organic architecture advocates that human-made structures should exist as part of nature rather than causing it harm. Ecological Architecture is an architectural concept that aims to minimise the environmental impact of buildings by reducing energy demand through appropriate material choices and construction methods suited to the climate and the characteristics of the site, while ensuring the highest efficiency in energy use [12]. Regenerative Design is a design approach that seeks to improve and revitalise natural systems instead of harming them. This concept goes a step beyond sustainability, aiming not only to reduce environmental impacts but also to create a positive cycle between humans and natural ecosystems. Biomimicry applies the evolutionary processes developed by nature over millions of years to devise innovative solutions that mimic nature. This discipline seeks to create sustainable and environmentally friendly designs by studying nature's strategies. Biophilic Design aims to strengthen the emotional connection between humans and nature. It seeks to enhance the positive effects of nature and improve mental well-being in built environments, creating a sense of closeness to nature through the use of natural elements, vegetation, natural light, and ventilation in interior spaces.

2. Theoretical framework and conceptual background

Biophilia and biomimicry are two complementary approaches that draw inspiration from nature but differ in their focus and application. The concept of biophilia, first introduced by Erich Fromm and later popularised by E.O. Wilson, refers to the innate human tendency to seek connections with nature and other forms of life. In design, biophilic principles are structured around three main categories: direct experiences (such as natural light, water, and vegetation), indirect experiences (such as natural materials, colours, and imagery), and spatial configurations that mimic natural settings. Biophilic environments have been shown to reduce stress, improve cognitive performance, and accelerate healing, particularly in healthcare and educational settings [13,14].

In contrast, biomimicry, derived from the Greek words bios (life) and mimesis (imitation), focuses not on emotional or sensory experiences but on functionally emulating nature's strategies to create efficient, sustainable, and resilient design solutions. As Janine Benyus (1997) emphasises, biomimicry involves learning from nature's models to replicate systems that use resources efficiently, eliminate waste, and adapt to change [15,16]. Biomimicry operates on three levels – organism, behaviour, and ecosystem – each providing

unique insights for innovation (e.g., using termite mounds as models for passive ventilation systems). Although the term biomimetic was first coined by Otto Schmitt in the 1960s, the concept gained global recognition after Benyus's book Biomimicry: Innovation Inspired by Nature, which argued for its adoption not only as a design tool but also as a philosophy for living in harmony with nature [17,18].

While biophilic design prioritises psychological and emotional well-being by fostering connections with nature, biomimicry emphasises nature's functional intelligence to address complex design challenges. The integration of these two perspectives offers a promising holistic framework for designing built environments that are both emotionally enriching and ecologically responsible.

Furthermore, the negative processes experienced after the Industrial Revolution have forced humanity to return to and protect nature. In this context, the idea of drawing inspiration from nature has come to the forefront. Biomimicry aims to develop innovative and sustainable solutions by learning from natural systems. For instance, biological adhesives inspired by sticky plants are now used in sectors such as medicine, industry, and construction. Today, transforming the cycles and principles of nature into design is less about mere imitation and more about observing how living beings cope with challenges, how they take precautions against them, and translating these behaviours into design [19,20]. In short, biomimicry encompasses far more than simply imitating nature. It focuses on understanding the complex and harmonious systems of nature, exploring how these systems ensure sustainability, and regarding nature not only as a resource but also as a guide and source of inspiration. According to Benyus, biomimicry is based on nine principles:

- In nature, sunlight is used as an energy source.
- Nature uses energy resources efficiently.
- Nature does not produce waste; everything is part of a cycle.
- Nature supports diversity.
- Nature rewards cooperation.
- Nature uses local resources.
- Nature adapts function to form.
- Nature takes advantage of the strength of limits.
- Nature has the power to regulate extremes [4].

According to Zari, there are three levels of biomimicry (Table 1):

- Ecosystem Level: mimics the holistic functioning of natural systems. The cyclical principles of nature are integrated into cities and built environments through biomimicry to ensure sustainability in waste management and resource use.
- Behavioural Level: draws inspiration from the behaviours of living beings. For example, the natural ventilation systems of termite mounds have inspired energy-efficient building designs.
- Organism Level: draws inspiration from the physical characteristics of living beings. For instance, the aerodynamic structure of the kingfisher's beak has been applied to reduce noise in the design of high-speed trains [16].

For example, termite mounds inspired the Eastgate Centre in Harare, Zimbabwe, where natural ventilation strategies reduced the need for conventional cooling and heating systems (Fig. 1).

Butterfly wings are among the most fascinating visual spectacles offered by nature; their colourful patterns and elegant structures inspire admiration. Beyond their aesthetic qualities, the wings of species such as the Common Rose butterfly (Pachliopta aristolochiae) also possess remarkable optical and thermal properties. In addition, biomimicry can be

observed at different levels, such as the self-cleaning ability of the lotus flower inspiring hydrophobic surfaces, furniture design mimicking natural forms, and the aerodynamic beak of the kingfisher reducing noise in high-speed trains (Fig. 2). Today, studies are being conducted to design more efficient solar panels inspired by these characteristics of butterflies.

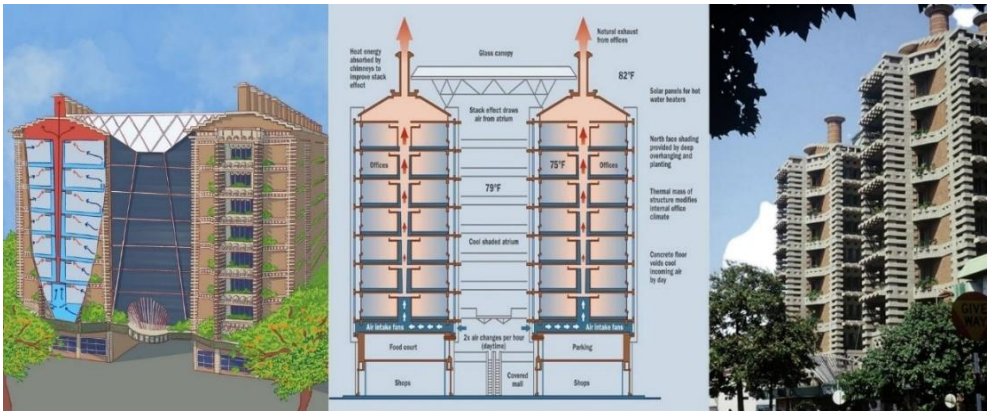

Fig. 1. Termite mounds and Eastgate Centre building section [18]

Table 1. Levels of biomimicry [16]

Level of Biomimicry		*Example - A building that mimics termites:*
Organism level (Mimicry of a specific organism)	*form*	The building looks like a termite.
	material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	*form*	The building looks like it was made by a termite; a replica of a termite mound for example.
	material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.
	function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example It may also function in the same way that a termite mound does in a larger context.
Ecosystem level (Mimicry of an ecosystem)	*form*	The building looks like an ecosystem (a termite would live in).
	material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.
	function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilising the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc in a similar way to an ecosystem for example.

Fig. 2. Examples of biomimicry

To answer the question "What is biophilic design?", it is first necessary to understand the concept of biophilia. The term was introduced in the 1960s by social psychologist and author Erich Fromm, who defined it as the opposite of necrophilia (the desire for dead bodies). Derived from the Greek words bio (life) and philia (love or desire), biophilia expresses a deep and heartfelt attraction that humans feel towards nature and natural systems. In other words, it means "love of life" or "love of living systems."

The concept of biophilia reflects the profound affection and interest that humans have developed over thousands of years of living in close connection with the natural environment. As a result of this long-term interaction, people feel an emotional bond with nature and derive great pleasure from spending time in it [19]. Experimental findings from the past thirty years indicate that biophilia is grounded in theories of reintegrating nature with the artificial environment, and that designs aesthetically enriched with natural elements not only enhance overall well-being but also have positive, restorative effects on human physiology. Wilson observed that people are psychologically, physically, biologically, and spiritually connected to nature – its forms, processes, and patterns – and that this connection contributes to embedding nature within the holistic framework of mental and physical well-being [3,20]. The relationship between humans and nature has emerged as one of the central themes of human history. As people have discovered the bond between the natural world and their surroundings, nature has become not only a resource but also a refuge and a source of inspiration. The concept of biophilia thus describes the deep emotional bond and fascination that people feel towards nature.

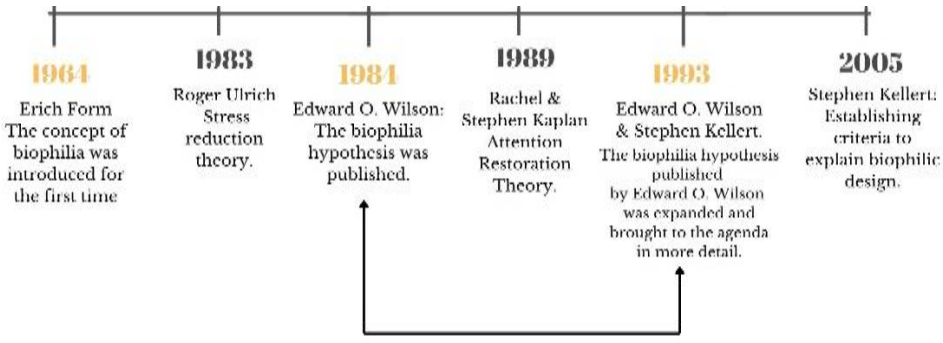

Fig. 3. Theories influencing the development of the biophilia concept [21]

By recognising that they are part of nature, people should respect and strive to understand it while making use of natural resources. This perspective views nature not only as a resource that benefits humans but also as an essential element of human life that responds to fundamental needs. The concept of biophilic design is rooted in biophilia and proposes a design approach that draws inspiration from natural elements and processes in the built environment. Its aim is to reduce human stress and anxiety levels by strengthening the human-nature connection. One of the most distinctive features that sets biophilic design apart from other environmentally friendly approaches is that it addresses not only the physical connections between humans and other living organisms but also the psychological one [22]. Biophilic design principles promote individuals' physical and mental well-being by incorporating strategies such as the use of natural light, vegetation, water features, and natural materials. For instance, it has been scientifically demonstrated that patients in hospital rooms with views of nature recover more quickly and require fewer painkillers than those in rooms without such views [23].

Table 2. Biophilic design principles identified by Kellert and Calabrese

Direct Experience of Nature	Indirect Experience of Nature	Experience of Space and Place
1. Light	9. Images of nature	19. Space and shelter as habitat
2. Air	10. Natural materials	20. Organization of complexity
3. Water	11. Natural colors	21. Integration of parts and the whole
4. Plant	12. Simulations of natural light and air	22. Temporary spaces
5. Animal	13. Evocation of nature	23. Flow and orientation
6. Climate	14. Richness of information	24. Cultural and ecological attachments in space
7. Natural landscape and ecosystem	15. Natural shapes and forms	
8. Fire	16. Signs of age, change, and time	
	17. Natural geometries	
	18. Biomimicry	

Biophilic design principles are a set of elements that integrate the natural world into human-made environments, enabling people to establish a closer connection with nature. These natural elements and processes help shape interiors, open spaces, and structures, contributing to the health and well-being of those who experience them. Their most fundamental purpose is to restore and repair the severed connections between humans and the natural world.

Direct Experience of Nature refers to the real contact humans have with various natural entities in their environment. This includes experiencing natural elements such as direct light, air, water, fire, plants, animals, meteorological conditions, natural landscapes, and ecosystems.

Indirect Experience of the Natural Environment refers to interactions with representations or evocations of nature within the built environment. This involves experiencing images of nature, natural materials, natural colours, simulated natural light and air, natural shapes and forms, richness of information, variation and change, the patina of age and time, natural geometries, biomimicry, and other elements reminiscent of nature [24].

Space and Place Experience refers to experiences that affect individuals through direct interaction with the characteristic spatial features of the natural environment, thereby

enhancing their health and well-being. This includes experiencing open, spacious, and sheltered areas; perceiving order within complexity; integrating parts into a whole; moving through transitional spaces; supporting mobility and orientation; and fostering attachment to cultural and ecological places [25].

4. Research methodology

In this study, bibliometric analysis was used to explore the relationships between the concepts of biophilia and biomimicry and to identify the potential contributions of combining these two concepts in the academic literature. Bibliometric analysis is a method that enables the quantitative examination of scientific publications and the identification of interactions and trends among them. Following the scientometric approach adopted by Fathi et al. (2024) in their global analysis of energy and building research, this study employs VOSviewer and Biblioshiny to map interdisciplinary trends in biophilic-biomimetic design [36]. This method provides comprehensive information about the scientific literature, allowing for an understanding of the development and future directions of a specific field. In this research, scientific maps were created using VOSviewer version 1.6.20 and R Studio Biblometrix Biblioshiny software for bibliometric analysis. These tools visualise the relationships between concepts, demonstrating that biophilia and biomimicry are key components of sustainable design thinking.

Expanded Data Sources: To overcome the limitation of relying solely on Web of Science, this study also incorporates Scopus, ensuring a more comprehensive bibliometric analysis, particularly for interdisciplinary fields such as interior design, environmental psychology, and architecture.

Data Collection:
Keywords: “Biophilia,” “Biophilic Design,” “Biomimicry,” “Biomimicry in Architecture.”
Time Frame: 2006–2024
Databases: Web of Science, Scopus
Criteria: Peer-reviewed articles, book chapters, and conference proceedings related to interior design and sustainability.
Analysis Tools:
VOSviewer: Conceptual clustering, network visualisation
R Studio Bibliometrix-Biblioshiny: Thematic evolution, citation analysis, keyword co-occurrence

Additionally, publications containing the keywords biophilia and biomimicry were collected by scanning the Web of Science database, and a detailed analysis was carried out. The collected data were evaluated to gain a clearer understanding of how the concepts of biophilia and biomimicry are addressed in interior design and the areas in which they are applied. These analyses highlighted the significance of these concepts in the academic literature and their potential for application. The research method diagram is presented in Table 2, and the research model is shown in Table 3.

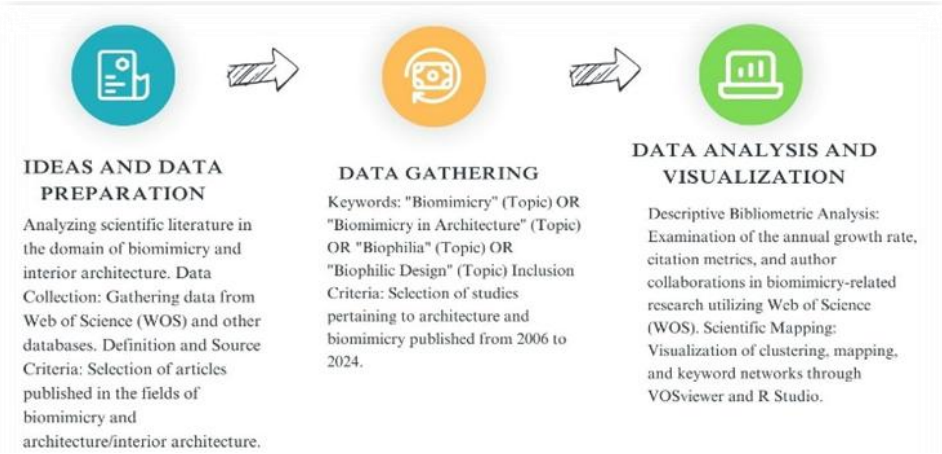

Fig. 4. Workflow for bibliometric analysis

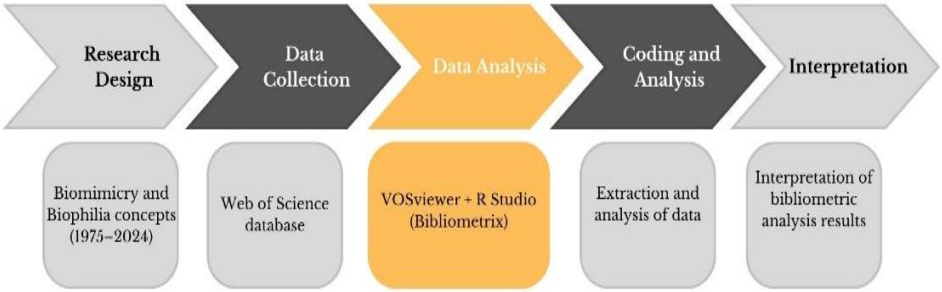

Fig. 5. Research design

The methodological flow of this study proceeded as follows:

- ***Data Collection***

Data Source: *The research data were obtained from the Web of Science Core Collection (WoS) database, a multidisciplinary and comprehensive resource widely used for scientific literature analysis.*

Keywords: *The keywords "biophilia" and "biomimicry" were used in the data collection process to identify relevant publications. These terms, applied in double quotes, were selected to filter documents directly related to the subject.*

Time Frame: *The study covered publications from 2006 to 2024, examining academic developments and outputs within this period.*

- ***Data Analysis***

Bibliometric Tools: *Analyses were conducted using VOSviewer and R Studio – Bibliometrix Biblioshiny software. Both were employed together because VOSviewer highlights relationships through visual network maps, while Biblioshiny provides more detailed insights into numerical data and temporal dynamics. Used in combination, they clarify both structural connections and thematic trends.*

The software was used to analyse and visualise scientific literature data, with the following functions applied:

- ***Network Maps:*** *Visualisation of the relationships between concepts and keywords.*
- ***Theme Maps:*** *Creation of thematic maps showing the areas in which research topics are concentrated.*
- ***Citation Analyses:*** *Examination of citation rates of publications and their distribution over time.*

Data Filtering and Categorisation: *The collected data were classified according to document types (articles, conference papers, book chapters, etc.) and citation counts. In addition, specific fields such as architecture, materials science, and energy efficiency from WoS categories were examined.*

- ***Creation of visual maps of scientific data***

Network Maps: Network maps showing the relationships between the concepts of biophilia and biomimicry were created using VOSviewer. These maps demonstrate the academic fields in which the two concepts are addressed together.

Theme Maps: Thematic analyses of biomimicry and biophilia were carried out using the R Studio – Bibliometrix Biblioshiny tool. These analyses also identified how the concepts have been integrated with various disciplines over time.

5. Findings

The studies show that a total of 68 documents have been published: articles (32), book chapters (5), books (1), and conference papers (27). The average citation count has been calculated as 6.824 per document, indicating that biomimicry topics attract significant attention in the academic literature (Fig. 6).

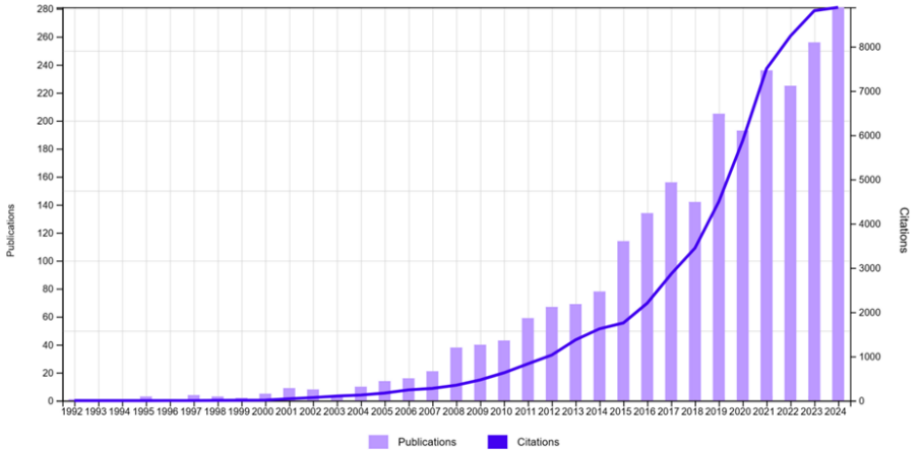

Fig. 6. Citation count and publications over time

The most influential publications in terms of citation count were produced by Zari (2018) [16] and Kennedy (2015) [29]. Kennedy's work, which addresses biomimicry as a pathway for sustainable innovation, has received 58 citations. Zari's studies on biomimicry-based urban planning and architecture have also drawn considerable attention for their innovative approaches.

Table 3. R Studio–Biblioshiny findings for biomimicry

Table 3 shows the main information table visualized in R Studio Bibliometrix Bibliosiny software. "Biomimicry," "biophilia," "sustainability," "nature-based design," and "architectural innovation" are the most frequently used terms. A total of 2,048 publications related to biomimicry were retrieved from the Web of Science (WoS) database, of which 68 were directly related to architecture. According to this table, Timespan (2006–2024): The data covers the years 2006–2024. Sources (41): The total number of sources (journals, books, etc.) in which the studies were published. Documents (68): The total number of publications examined. Annual Growth Rate (10.47%): The annual growth rate of publications is 10.47%. Authors (143): A total of 143 different authors contributed. Authors of single-authored docs (23): 23 studies have a single author. International Co-Authorship (13.24%): 13.24% of the publications had international co-authorship. Co-Authors per Doc (2.28): There are an average of 2.28 authors per article. Author's Keywords (208): The total number of keywords used in the studies. References (2048): A total of 2048 citations (references) were found across all documents. Document Average Age (7.07): The average age of the documents is around 7 years. Average citations per doc (6.824): An average of 6.82 citations were made per article.

Additionally, according to R Studio findings, the highest number of publications were produced in the United States, New Zealand, and Australia. This indicates that biomimicry is more frequently addressed in sustainability-focused projects in developed countries. Turkey, by comparison, ranks closer to the middle (Fig. 7).

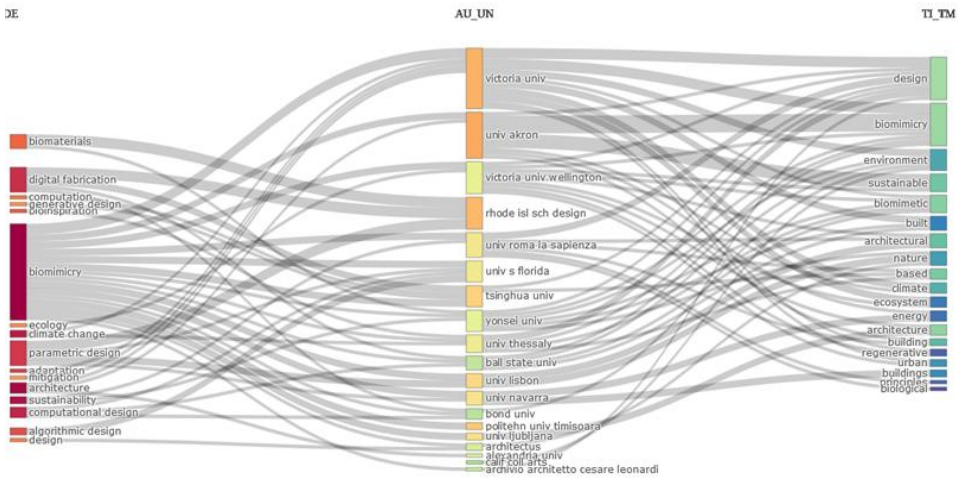

Fig. 7. Distribution by affiliation

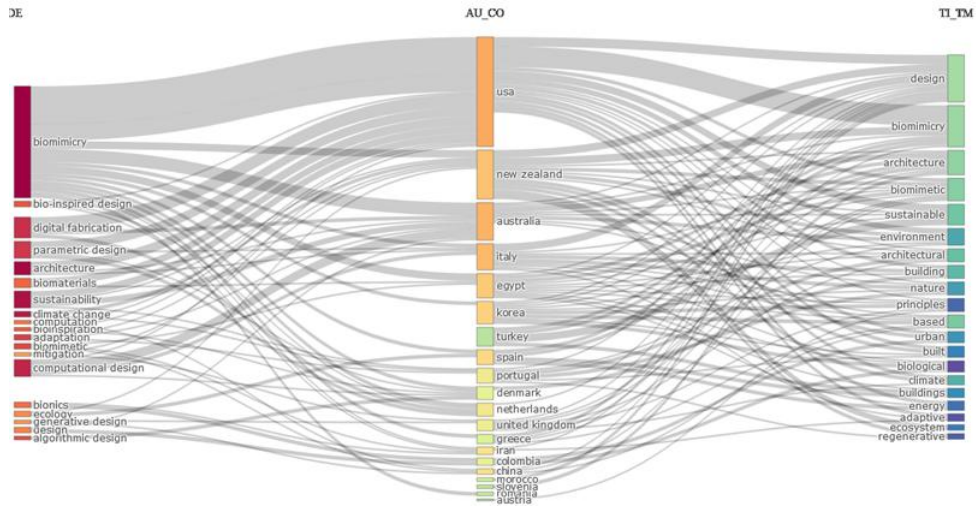

Fig. 8. Distribution by countries

The visuals above show the distribution of publications by country (Fig. 8). Red areas represent keywords, yellow areas represent countries, and blue areas represent words included in publication titles.

Fig. 9. Word cloud of biomimicry

The findings from VOSviewer indicate that, in the analysis of 182 documents, the largest cluster is sustainable architecture at 23%, followed by biomimetic materials at 18% and structural systems at 15%. According to the research, disciplines such as materials science, architecture, nanotechnology, and biomaterials are the main contributing fields in the areas of biomimicry and biophilic design (Fig. 9). As shown in the clusters above, the green, blue, and red clusters occupy a substantial area. The green clusters contain technical and design-oriented terms such as “computational design” and “adaptive reuse,” while the blue clusters address environmental and sustainability issues such as “climate change” and “sustainable design holism.” The red clusters include more general design approaches, such as “cross-disciplinary team” and “design” (Fig. 9).

Figure 10 shows the distribution map of country-level scientific production. According to this figure, the countries with the most influential publications are represented on the world map using a gradient from dark blue to light blue, indicating varying levels of scientific output (Fig. 10).

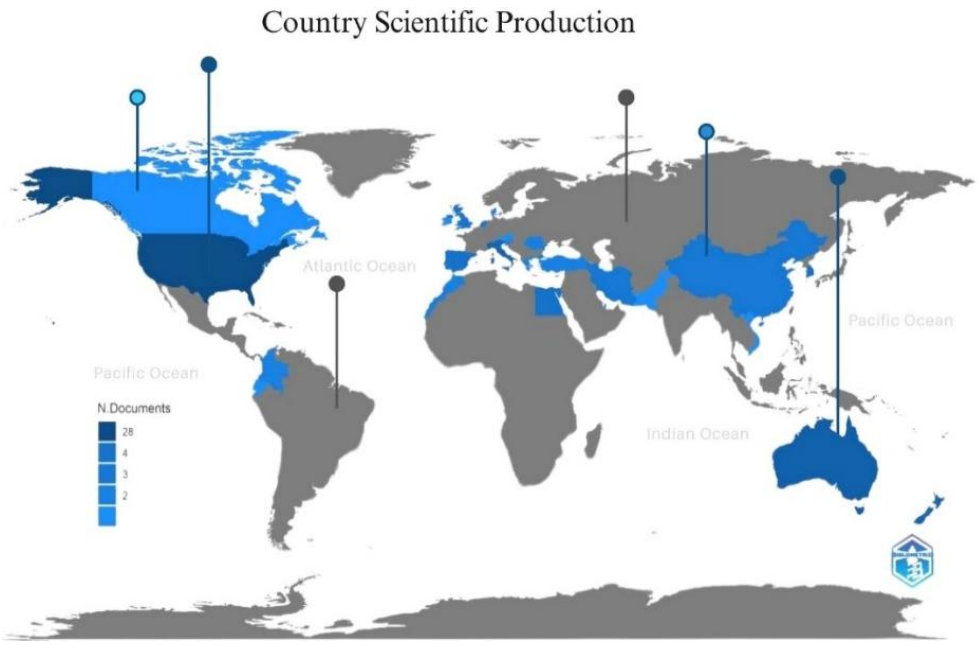

Fig. 10. Distribution by countries (map)

6. Discussion

Bibliometric analysis reveals a growing academic interest in the integration of biophilic design and biomimicry, particularly in the context of sustainable interior design. The findings highlight a steady increase in publications since 2006, with an annual growth rate of 10.47%, demonstrating that these nature-inspired approaches are gaining momentum as viable solutions for enhancing both human well-being and environmental sustainability. However, despite this upward trend, the research also highlights a persistent gap between theoretical discourse and practical application, pointing to the need for more empirical studies and interdisciplinary collaboration.

The most influential studies in this field, such as Zari (2018) and Kennedy (2015), underscore the potential of biomimicry in urban planning and sustainable innovation. The high citation counts reflect the academic community's recognition of biomimicry as a transformative design paradigm. At the same time, the frequent co-occurrence of keywords such as biophilia, sustainability, and nature-based design reinforces the interconnectedness of these concepts and suggests a holistic approach that combines psychological benefits with ecological efficiency.

Geographically, the United States, New Zealand, and Australia lead in research output due to their strong emphasis on sustainability and green architecture. Türkiye's moderate contribution reflects its emerging participation, but greater integration of biophilic and biomimetic principles into local design practices could enhance its impact. The disciplinary clusters identified through VOSviewer – specifically sustainable architecture (23%), biomimetic materials (18%), and structural systems (15%) – demonstrate a wide range of applications for these concepts, spanning from macro-scale urban solutions to micro-scale material innovations.

A critical observation is the underrepresentation of integrated biophilic–biomimetic frameworks in the interior design literature. While both concepts are often treated separately, their combined application has been under-researched, despite their complementary strengths. For example, biomimicry's focus on functional efficiency (e.g., energy-efficient ventilation systems inspired by termite mounds) can be effectively combined with biophilic design's emphasis on sensory and emotional well-being (e.g., indoor green walls). This integration can produce spaces that are not only resource-efficient but also psychologically restorative – a dual benefit aligned with the demands of contemporary sustainable design.

Emerging technologies such as 3D/4D printing and bio-based materials offer new opportunities to advance this synthesis. Future research should explore how these innovations can facilitate adaptable and regenerative interiors that dynamically respond to environmental and human needs. Furthermore, longitudinal studies evaluating the real-world performance of integrated biophilic–biomimetic designs – particularly in terms of energy efficiency, occupant health, and productivity – will help bridge the gap between theory and practice.

In conclusion, this study positions biophilic design and biomimicry as complementary foundations for sustainable interior architecture. By fostering interdisciplinary dialogue and evidence-based practices, researchers and practitioners can develop design solutions that align ecological responsibility with human-centred well-being – an essential step towards resilient and regenerative built environments.

Category	Reference
Biophilic Design and Interior Spaces	Browning, W. D., Ryan, C. O., & Clancy, J. O. (2020). *14 Patterns of Biophilic Design: Improving Health and Well-Being in the Built Environment.* Terrapin Bright Green LLC.
	Gillis, K., & Gatersleben, B. (2015). A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design. *Buildings, 5*(3), 948-963.
	Söderlund, J., & Newman, P. (2022). *Biophilic Architecture: Designing for the Future.* Routledge.
	Joye, Y., & De Block, A. (2021). Nature-Based Design: How Biophilic Design Influences Product, Interior, and Architecture Evaluation. *Journal of Environmental Psychology, 74*, 101572.
Biomimicry and Sustainable Design	Badarnah, L. (2022). *Biomimicry for Designers: Applying Nature's Processes and Materials in the Real World.* Thames & Hudson.
	Zari, M. P., & Hecht, K. (2020). Biomimicry for Regenerative Built Environments: Mapping Design Strategies for Producing Ecosystem Services. *Building and Environment, 177*, 106874.
	Pawlyn, M. (2021). *Biomimicry in Architecture: A Review of Theory and Practice.* RIBA Publishing.
	Speck, O., & Speck, T. (2023). Biomimetic Materials in Architecture and Building Technology: From Molecular to Macro Scale. *Advanced Materials, 35*(12), 2105197.
Integrated Approaches and Interdisciplinary Studies	Robinson, A., & Pallasmaa, J. (2023). *Biophilic and Biomimetic Interiors: Bridging Human Wellbeing and Ecological Resilience.* Wiley.
	Fathi, S., & Ennos, R. (2024). Bio-Inspired Adaptive Building Skins: Combining Biophilia and Biomimicry for Energy Efficiency. *Energy and Buildings, 298*, 113543.
	Kellert, S., & Finnegan, B. (2023). *The Practice of Biophilic and Biomimetic Design.* Island Press.
	Askari, F., & Habibi, A. (2025). *Neuro-Urbanism and Biophilic Design: Enhancing Cognitive Health Through Nature-Inspired Spaces*. *Frontiers in Psychology, 16*, 10289.

Biophilic design and biomimicry have become integral components of sustainable interior design. Both concepts aim to enhance psychological well-being and promote environmental sustainability by integrating natural elements into human life. In the literature, however, the integration of these two approaches has not previously been explored; they have generally been evaluated separately. The aim of this research is to identify, through bibliometric analysis, the concepts most frequently associated with biophilic design and biomimicry, and to examine the advantages that may arise from their integration.

Askahi et al. (2025) combine the concept of the "smart city" with neuroscience, highlighting innovative approaches such as biophilic design (cities in harmony with nature) and sensory accessibility. They also recommend long-term studies on neurological impacts and the applicability of these approaches in low-income communities for future research [35].

The parallel evolution of biophilic and biomimetic design underscores their shared objective: creating environments that promote human well-being while respecting ecological limits. However, their combined potential remains underexplored in interior design contexts. By uniting the psychological benefits of biophilia with the systemic efficiency of biomimicry, designers can craft spaces that nurture occupants while conserving resources. For example, integrating biomimetic ventilation systems inspired by termite mounds with biophilic green walls can result in interiors that are both energy-efficient and emotionally restorative.

Evaluations show that biophilic design enables individuals to establish visual and physical connections with nature, reducing stress levels and enhancing focus [17]. Its positive effects on satisfaction, productivity, and learning processes in educational and workplace environments are particularly noteworthy [30]. Additionally, Ulrich's (1984) studies indicate that biophilic design can accelerate the healing process in healthcare facilities [26]. Biomimicry transforms design and engineering practices by drawing inspiration from natural processes. Isaac and Usanga (2023) [31] highlight its potential for achieving energy efficiency, while Garcia (2017) argues that innovative and sustainable design frameworks can be created through the combination of biophilic design and biomimicry [32]. Saylam (2019) notes that biophilic elements enhance mental well-being [5], and Abbaslı's (2019) studies reveal that biomimicry [21], when combined with parametric designs, achieves notable results in terms of both energy efficiency and aesthetics. Habibi (2017) critically examines the longstanding dichotomy in landscape aesthetics by addressing the conceptual tension between two main paradigms: the Conceptual-Cognitive Model, developed primarily by Allen Carlson, and the Non-Conceptual-Imaginary Model associated with Arnold Berleant. Rather than favouring one over the other, Habibi proposes a hybrid theoretical framework that emphasises the dynamic interplay between rational, analytical understanding and emotional, imaginative experience in aesthetic perception. This philosophically grounded approach highlights the importance of integrating both scientific–conceptual and experiential–imaginative dimensions when evaluating landscape aesthetics. The synthesis not only challenges binary thinking in environmental aesthetics but also contributes to a more nuanced and holistic theoretical foundation for the field (Habibi, 2017) [33-36].

Fathi et al. (2024) conducted a global scientometric review of energy and building research from 2015 to 2020, analysing 1,543 Scopus-indexed articles. Using VOSviewer and PRISMA-guided methods, they mapped keyword associations, journal impact, citation metrics, and co-authorship and country networks. While the United States and China led in both publication volume and citation power, the most prominent topics included energy performance, sustainable building design, BIM, and LCA. Emerging frontiers involved embodied carbon, optimisation of existing building stock, and the integration of digital technologies. The authors emphasise the need for supportive policies, cross-country

collaboration, and further research in underexplored areas such as prefabrication and carbon modelling using machine learning.

7. Suggestions and conclusions

In this study, the use of VOSviewer and R Studio's Bibliometrix–Biblioshiny software provided a comprehensive and systematic overview of the position of biophilic design and biomimicry in the scientific literature. The bibliometric analyses revealed a steady increase in the number of academic publications addressing these concepts over the years, reflecting their growing importance within broader discourses such as sustainability, energy-efficient architecture, and nature-inspired design paradigms (Fathi et al., 2024). The findings also highlight the significance of countries such as the United States, New Zealand, and Australia as leading contributors to academic output in this field.

Furthermore, the data demonstrate an emerging trend towards incorporating biophilic and biomimetic design principles into technologies such as 3D and 4D printing, biotechnology, biomaterials, and nanotechnology, collectively enhancing the innovative and regenerative potential of interior and architectural design. This integration not only expands functional and aesthetic possibilities but also fosters new interdisciplinary collaborations, reinforcing the transformative role of these approaches in shaping the future of sustainable built environments.

In conclusion, this study has comprehensively examined the contributions of biophilic design and biomimicry to the advancement of sustainable interior design practices. The analysis underscores the vital role of biophilic design in promoting psychological well-being, while also emphasising the capacity of biomimicry to deliver energy-efficient and innovative architectural solutions inspired by natural systems. Through a critical review of existing literature, the research has demonstrated the broad applicability of these two concepts across various design disciplines, highlighting their potential to encourage multidisciplinary and integrative approaches. Furthermore, it has been observed that the combination of biophilic and biomimetic principles can create interiors that not only enhance human well-being but also reduce environmental impact through improved energy performance. Despite their individual strengths, the integration of these approaches has been under-researched in current academic discourse. This study is therefore positioned as a fundamental step towards the development of a new hybrid design methodology that synthesises the experiential and functional benefits of biophilic and biomimetic paradigms, paving the way for future experimental and theoretical research in this emerging field.

In conclusion, this study has thoroughly examined the contributions of biophilic design and biomimicry to sustainable interior design. The role of biophilic design in enhancing psychological well-being and the role of biomimicry in providing energy efficiency and innovative solutions have been emphasised. The literature review has revealed the wide application potential of these concepts and the opportunities they offer for multidisciplinary approaches. It has been observed that studies integrating these two concepts can contribute to energy efficiency while also improving human well-being. The analysis indicates that there is a gap in the literature on this subject, and this study has shown that a new design methodology may emerge from their combination in future research.

This study has made significant contributions to the academic community by offering insights at both theoretical and practical levels. It has established a conceptual and methodological foundation that can inform and inspire future research in sustainable interior design. In particular, the research advances academic understanding by situating biophilic design and biomimicry within the context of next-generation technologies and scientific

mapping techniques. These innovative approaches enable a more nuanced and multidimensional examination of the social, economic, and environmental impacts of interior architecture practices.

By integrating ecological awareness into design thinking, this study promotes a paradigm shift towards more resilient and adaptable interior environments. The findings highlight the potential for future research to deepen this discourse through interdisciplinary and evidence-based methodologies.

Potential future research directions include:

- Empirical field studies evaluating the implementation and performance of integrated biophilic and biomimetic interior design strategies across various building typologies.
- Quantitative investigations into the relationships between spatial design features and measurable outcomes in occupant well-being, productivity, and energy efficiency.
- Exploration of cutting-edge technologies such as bio-based materials, responsive design systems, and AI-enabled simulation tools to support the development of adaptable and regenerative interiors.

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